OPERATIONS RESEARCH (ME506PC)

COURSE PLANNER

I. Course Overview:

Operations Research (O.R.) is the application of advanced analytical methods to help make better decisions. Since its inception nearly 70 years ago, O.R. has contributed billions of dollars in benefits and savings to corporations, government, and the nonprofit sector.

Operations Research is often concerned with determining the maximum (of profit, performance, or yield) or minimum (of loss, risk, or cost) of some real-world objective. Originating in military efforts before World War II, its techniques have grown to concern problems in a variety of industries. Applications of O.R. are abundant in industry such as airlines, manufacturing companies, service organizations, military branches, and in government. The range of problems and issues to which field of O.R. has contributed insights and solutions are vast. Some of it includes scheduling airlines, both planes and crew, deciding the appropriate place to place new facilities such as a warehouse or factory, managing the flow of water from reservoirs, identifying possible future development paths for parts of the telecommunications industry, establishing the information needs and appropriate systems to supply them within the health service, and identifying and understanding the strategies adopted by companies for their information systems. Other major areas of O.R. applications include Computing and information technologies, Environment, energy, and natural resources, Financial engineering, Manufacturing, Service sciences, Supply chain management, Marketing Engineering, Policy modeling and public sector work, design optimization, Revenue management, Inventory control, optimal production planning and control, Transportation, Network optimization, Allocation problems, Facility location, Assignment Problems, Vehicle Routing, Transportation, Scheduling, Personnel staffing and Waiting Line models.

Course purpose:

The course is intended to cover some of the analytical methods like Dynamic Programming, Simulation Methods, Linear Programming Methods, Transportation, Assignment, Sequencing, Replacement, Theory of Games, Analytical Waiting Lines and Inventory Models to help make better decisions.

II. Pre-requisites:

The Knowledge of following subjects is essential to understand the subject

1. Knowledge in basic manufacturing processes
2. Logical and analytical reasoning skills
3. Mathematical concepts concerning co-ordinate geometry, linear algebra, matrices and calculus
4. Basic Probability & Statistics
5. Numerical Methods – Finite Difference method

III. Course Objective

1. Understanding the mathematical importance of development of model in a particular optimization model for the issue and solving it.
2. Understanding of need for optimization in scarce resources
3. Understanding of real time problems related to transportation and inventory management

IV. Course Outcome:

Sr. No.	Description	Blooms Taxonomy Level
CO1	Able to understand the advanced analytical methods like Dynamic Programming, Simulation Methods, Linear Programming Methods, Transportation, Assignment, Sequencing, Replacement, Theory of Games, Analytical Waiting Lines and Inventory Methods to help make better decision	**L1: Knowledge**
CO2	Able to formulate the real life problem into an appropriate mathematical model	**L3: Application**
CO3	Able to choose and apply the appropriate techniques to solve the formulated model	**L4: analysis**
CO4	Able to test the model and its solution	**L6: Evaluation**
CO5	Able to implement the solution	**L3: Application**

V. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	Ability to apply acquired knowledge of science and engineering fundamentals in problem solving.	3	Assignments and Exams
PO2	Ability to undertake problem identification, formulation and providing optimum solution in software applications.	3	Assignments and Exams
PO3	Ability to utilize systems approach in designing and to evaluate operational performance of developed software.	3	Assignments and Exams
PO4	Graduates will demonstrate an ability to identify, formulate and solve complex information technology related problems.	2	--
PO5	Graduate will be capable to use modern tools and packages available for their professional arena.	2	Assignments and Exams
PO6	Understanding of the social, cultural responsibilities as a professional engineer in a global context.	--	--
PO7	Understanding the impact of environment on engineering designs based on the principles of inter-disciplinary domains for sustainable development.	1	--
PO8	Ability to understand the role of ethics in professional environment and implementing them.	--	--

PO9	Competency in software development to function as an individual and in a team of multidisciplinary groups.	2	--
PO10	Ability to have verbal and written communication skills to use effectively not only with engineers but also with community at large.	2	--
PO11	Ought to have strong fundamentals in Information Technology and be able to have lifelong learning required for professional and individual developments.	1	--
PO12	Be able to design, implement and manage projects in Information Technology with optimum financial resources with, environmental awareness and safety aspects	--	Assignments and Exams

VI. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes (PSOs)		Level	Proficiency assessed by
PSO1	The student will be able to apply the knowledge of Mathematics, Sciences and engineering fundamentals to formulate, analyze and provide solutions for the problems related to Mechanical engineering and communicate them effectively to the concerned.	2	Lectures, Assignments
PSO2	Design mechanical systems in various fields such as machine elements, thermal, manufacturing, industrial and inter-disciplinary fields by using various engineering/technological tools to meet the mercurial needs of the industry and society at large.	2	Projects
PSO3	The ability to grasp the latest development, methodologies of mechanical engineering and posses competent knowledge of design process, practical proficiencies, skills and knowledge of programme and developing ideas towards research.	3	Guest Lectures

VII. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Program Outcomes (POs)											
PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
3	2	2	-	-	-	-	-	2	1	-	2
3	3	2	-	1	-	-	-	2	1	-	2
3	3	2	1	1	-	-	-	2	1	-	2
3	3	2	1	1	-	-	-	2	1	-	2
3	3	2	1	1	-	-	-	2	1	-	2
3.00	**2.80**	**2.00**	**1.00**	**1.00**	**-**	**-**	**-**	**2.00**	**1.00**	**-**	**2.00**

PROGRAM SPECIFIC OUTCOMES:

Course Outcomes (COs)	Program Specific Outcomes (PSOs)		
	PSO1	PSO2	PSO3
CO1.	3	2	1
CO2.	3	2	1
CO3.	3	2	1
CO4.	3	2	1
CO5.	3	2	1
Average	**3.00**	**2.00**	**1.00**

VIII. Course Contents – As per JNTUH Syllabus:

UNIT – I: Introduction: Development – Definition – Characteristics and Phases – Types of models – Operations Research models – applications. **Allocation:** Linear Programming Problem Formulation – Graphical solution – Simplex method – Artificial variables techniques: Two–phase method, Big-M method.
UNIT – II: Transportation Problem: Formulation – Optimal solution – unbalanced transportation problem – Degeneracy. **Assignment Problem** – Formulation – Optimal solution - Variants of Assignment Problem – Traveling Salesman problem.
UNIT – III: Sequencing: Introduction – Flow –Shop sequencing – n jobs through two machines – n jobs through three machines – Job shop sequencing – two jobs through 'm' machines. **Replacement:** Introduction – Replacement of items that deteriorate with time – when money value is not counted and counted – Replacement of items that fail completely-Group replacement.
UNIT – IV: Theory of Games: Introduction – Terminology – Solution of games with saddle points and without saddle points – 2 x 2 games – dominance principle – m x 2 & 2 x n games – graphical method. **Inventory:** Introduction – Single item, Deterministic models – Purchase inventory models with one price break and multiple price breaks – Stochastic models – demand may be discrete variable or continuous variable – Single period model and no set up cost.
UNIT – V: Waiting Lines: Introduction – Terminology - Single Channel – Poisson arrivals and Exponential service times – with infinite population and finite population models – Multichannel – Poisson arrivals and exponential service times with infinite population. **Dynamic Programming:** Introduction – Terminology-Bellman's Principle of Optimality – Applications of dynamic programming- shortest path problem – linear programming problem.

Relevant syllabus for GATE:
Linear programming, simplex method, transportation, assignment, network flow models, simple queuing models, Deterministic Inventory control models.

Relevant syllabus for IES:
Linear Programming - Graphical and Simplex methods, Transportation and Assignment models. Single server Queuing model. Inventory control, EOQ model.

IX. Lesson Plan:

Lecture No.	Unit No.	Date	Topics to be covered	Content to be covered under each topic	Link for PPT	Link for PDF	Course learning outcomes	Teaching Methodology	Reference
1	1	15-09-21	Introduction: OR	• Introduction, • Why is Operations research	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L2-Understand	Board and PPT	OR/ Taha /PHI
2		16-09-21	Applications, types of OR	• Applications of operations research • Operation Research Models	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L2-Understand	Board and PPT	OR/ Taha /PHI
3		18-09-21	Linear Programming	• Problem Formulation • Objectives formulations • Graphical Solution	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L2-Understand	Board and PPT	OR/ Taha /PHI
4			**Student PPT**						
5		22-09-21	Simplex Method: Minimization Problem	• Minimization problem• Slack Variable • Entering Variable • Leaving Variable	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L2-Understand	Board and PPT	OR/ Taha /PHI

6		23-09-21	Simplex Method: Maximization Problem	• Maximization Problem• Slack Variable • Entering Variable • Leaving Variable	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L2-Understand	Board and PPT	OR/ Taha /PHI
7		25-09-21	Artificial Variable Techniques	• Two Phase Method • Big M method • Duality Condition	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
8			**Student PPT**						
9		29-09-21	Two Phase Method	• Concept of two phase method • Adding slack variables • Adding surplus Variables • Conversion of objective function from minimization to maximization • Optimal solution	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing		Board and PPT	OR/ Taha /PHI

10		30-09-21	Big M method	• Concept of Big M method • Assigning values to each of the artificial variables • Conversion of inequalities into equalities	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing		Board and PPT	OR/ Taha /PHI
11		25-09-21	Duality	• Concept • Duality condition in linear programming • Objective function • Slack variables	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing		Board and PPT	OR/ Taha /PHI
12			**Student PPT**						
13		06-10-21	Problems	Examples	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
14		07-10-21	Problems	Examples	https://drive.google.com/drive/folders/1AWYROsieEkCs7ptuERdiB2USmCNJaqX3?usp=sharing	https://drive.google.com/drive/folders/17S4_BUkAENgUiIk6BqFu-z1YQe7Sdq-d?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI

15		09-10-21	Transportation Problem	• Introduction, • Application • Classification • Formulation	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
16			**Student PPT**						
17	**2**	20-10-21	Optimal Solution	• Theory • Assumptions • Prerequisites • Formulation of Transportation Problem	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L3 apply	Board and PPT	OR/ Taha /PHI
18		21-10-21	Solving Transportation Problem	• Formulation of Transportation problem as LPP • Basic feasible solution • Optimal solution	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
19		23-10-21	Types of transportation Problems	• Demand • Supply • Balanced transportation Problem •UnbalancedTransportation Problem	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L3 apply	Board and PPT	OR/ Taha /PHI

20			**Student PPT**					
21		27-10-21	Basic feasible solution models (BFSM)	• North-West(N-W) Corner Rule • Least Cost Method (or The Matrix Minimum Method) • (Vogel's Approximation Method [VAM] (or Penalty Method	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
22		28-10-21	. North-West(N-W) Corner Rule	• Introduction • Determine balanced or unbalanced • Identification of least cost • Optimal Sequence	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L3 & L4 Apply and Analyze	Board and PPT	OR/ Taha /PHI
23		30-10-21	Least Cost Method	Introduction • Determine balanced or unbalanced • Identification of least cost • Optimal Sequence	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L3 & L4 Apply and Analyze	Board and PPT	OR/ Taha /PHI

24			**Student PPT**						
25		03-11-21	(Vogel's Approximation) Method	• Introduction • Problem Formulation • Identification of penalties • Optimal Sequence • Initial Basic Feasible Solution	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
26		06-11-21	Unbalanced Transportation Problem	• Introduction • Condition • Dummy Origin • Feasible Solution for UTP • Modified Transportation Problem	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L1, L2, L3 and L4	Board and PPT	OR/ Taha /PHI
27		10-11-21	Assignment Problem	• Introduction • Concept • Problem Formulation • Models • Simplex Method • Hungarian Method	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L1, L2, L3 and L4	Board and PPT	OR/ Taha /PHI
28			**Student PPT**						

29		11-11-21	Hungarian Method	• Introduction • Principles of Hungarian • Procedure • Initial Basic Feasible Solution	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
30		13-11-21	Travelling Sales man Problem	• Introduction • Theory • Applications • Models	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
31		17-11-21	Branch and Bound algorithm	• Introduction • Theory • Application to TSP • Example	https://drive.google.com/drive/folders/1Qj9H3pFkpfBItHRptDi7InbJr6F8QZE_?usp=sharing	https://drive.google.com/drive/folders/1XVXpIghSprwMnlE5SWdRT_Z9DJVaafH1?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
32			**Student PPT**						
33	**3**	18-11-21	Sequencing: Introduction	• Introduction• Concept• Application in real life• Models• Classification	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI
34		20-11-21	Sequencing Techniques	• Shortest Processing Rule (SPT) • Due Date •First Come First Serve	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L1 & L2 Understand	Board and PPT	OR/ Taha /PHI

35		24-11-21	Sequencing: Models	• Processing of n jobs through single machine • Processing n jobs through two machines. • Processing n jobs through three machines. • Processing two jobs through m machines. • Assumptions	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L3 & L4 Apply and Analyze	Board and PPT	OR/ Taha /PHI
36			**Student PPT**						
37		25-11-21	Processing of N jobs through two machines	• Introduction • Concept • Procedure • Example • Johnson's Algorithm • Models	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L3 & L4 Apply and Analyze	Board and PPT	OR/ Taha /PHI
38		27-11-21	Processing n jobs through three machines	• Introduction • Theory • Conversion of three jobs problem into two jobs	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L3 & L4 Apply and Analyze	Board and PPT	OR/ Taha /PHI

39		01-12-21	Processing two jobs through m machines.	• Introduction • Concept • Example • Graphical Solution	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing		Board and PPT	OR/ Taha /PHI
40			**Student PPT**						
41		02-12-21	Replacement Theory	• Introduction • Applications • Models • Examples • Replacement decisions	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
42		04-12-21	Types of Replacement Problems	• Replacement policy for items, efficiency of which declines gradually with time without change in money value. • Replacement policy for items, efficiency of which declines gradually with time but with change in money	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI

				value. • Replacement policy of items breaking down suddenly • Individual replacement policy • Group replacement policy • Staff replacement					
43			**Student PPT**						
44		08-12-21	Replacement of items that deteriorate with time	• Introduction • Replacement Decisions • When t is a continuous variable • When t is a discrete variable	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
45		09-12-21	when money value is not counted and counted	• Introduction • Depreciation • Future Value • NPV	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI

46		11-12-21	Replacement of items that fail completely	• Introduction • Conditions • Individual Replacement Policy • Group Replacement Policy • Mortality Tables	https://drive.google.com/drive/folders/1tvY8Mfdr2tnM6p3HxduuZkIiHMZ3vgoA?usp=sharing	https://drive.google.com/drive/folders/1OCVeIrsLLd1gUFgMejZWGxGUZYLt42yf?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
		Students PPT							
47	**4**	15-12-21	Theory of Games	• Introduction, Motivation • Concept • Terminology • Applications	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing	L2 Understand	Board and PPT	OR/ Taha /PHI
48		16-12-21	Solution of games with saddle points	• Introduction • What is saddle point • Role of saddle point in game theory • Rules for saddle point	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI

49		18-12-21	Solution of games without saddle points	• Introduction • Rectangular Game • Properties for optimal mixed strategies • Example of 2*2 Model	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
		Students PPT							
50		22-12-21	2 x 2 games-dominance principle	Introduction • Theory of dominance • Dominance Rules • Example	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
51		23-12-21	m x 2 & 2 x n games-Graphical method	• Introduction • Payoff Matrix • Maximum point • Maxmin point	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
52		29-12-21	Inventory	• Induction • Definition • Inventory types • Importance of Inventory in production	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
		Students PPT							

53		30-12-21	Inventory Models	• Introduction • Inventory Costs -Ordering Cost -Shortage Cost -Inventory Carrying Cost • Derivation of EOQ • Reorder Point	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
54		05-01-22	Deterministic models	• Introduction • Theory • With one price • With multiple price breakouts	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
55		06-01-22	Stochastic Models	• Introduction • Definition • Models • Demand Variable - Continuous - Discrete	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
		Students PPT							
56		06-01-22	Single period model and no setup cost	• Introduction • Examples • Over stocking cost • Under stocking cost • Discrete Probabilisti	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI

				c demand model					
57		08-01-22	Waiting Lines	• Introduction • Theory • Application • Terminology -Arrival - Service	https://drive.google.com/drive/folders/1dtk4rv49RbhaXPSAUqXrN2LD5Ion-tRk?usp=sharing	https://drive.google.com/drive/folders/1pvXJ5nqkprGuw8MbHYl-acwl-mgvLNu-?usp=sharing		Board and PPT	OR/ Taha /PHI
58		08-01-22	Single channel	• Introduction • Input/Output • Poisson Arrivals • Infinite population models • Arrival Types - Random Arrival - Scheduled Arrival	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI
		Students PPT							
59	**5**	11-01-22	Queue Discipline Models	•Introduction• First in First Out (FIFO)• Last-in-first-out (LIFO) • Service in random order (SIRO)•		https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI

60		11-01-22	Service Times	• Introduction • Exponential service times Finite population Infinite population Mean service rate Mean Arrival rate	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI
61		12-01-22	Dynamic Programming	• Introduction • Theory • Application • Terminology	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI
		Students PPT							
62		12-01-22	Bellman's principle of optimality	• Introduction • Discrete Time, certainty • Principles • Maximum Utility conditions	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI

				Shortest processing time first (SPT) • • Service according to priority (PR)	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing				
63		17-01-22	Shortest Path Problem	• Introduction • Principle of Optimality • Example	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI
64		17-01-22	linear programming problem	• Introduction • Models • Optimality • Examples	https://drive.google.com/drive/folders/1nWBbAJawVCEqxVY1qeBgwm9DOCiDA-KH?usp=sharing	https://drive.google.com/drive/folders/1C_TBN-ay0IAod98YoacRHlpSMryzy0oJ?usp=sharing		Board and PPT	OR/ Taha /PHI

A) TEXT BOOKS:

1. Operations Research / N.V.S. Raju / SMS
2. Operations Research / ACS Kumar / Yes Dee

B) REFERENCES:

3. Operations Research /J. K. Sharma / MacMilan.
4. 4. Operations Research /A. M. Natarajan, P. Balasubramaniam, A. Tamilarasi / Pearson.

Question Bank:

Short Anser Type Question

	UNIT-I		
1	a. Explain the applications ofOR? b. Explain advantages ofOR? c. Explain scope ofOR?	Understanding	1,2
2	Explain the terminology involved in formulating a linear programming problem?	Analysing	1,3

3	Solve the following LP problem graphically Maximize $z = x_1 + 2x_2$ S.T $x_1 + x_2 \leq 1$, $0.5x_1 + x_2 \geq 2$, $x_1, x_2 \geq 0$	Applying	1,5
4	Solve the following LP problem graphically. Maximize $z = 2x_1 + x_2$ S.T $x_1 + 2x_2 \geq 10$, $x_1 + x_2 \leq 6$, $x_1 - x_2 \leq 2$, $x_1 + 2x_2 \geq 1$ $x_1, x_2 \geq 0$	Applying	1,5

1	a. Write the general Mathematical model of transportationproblem? b. What do you understand by degeneracy in a transportationproblem?	Analysing
2	A Company has three plants at locations A,B and C which supply to warehouses located at D,E,F,G and H. monthly plant capacities are 800,500 and 900 respectively. Monthly warehouse requirements are 400, 500,400 and 800 units respectively. Unit transportation cost in rupees are given below.	Applying

	D	E	F	G
A	5	8	6	6
B	4	7	7	6
C	8	4	6	6

Determine an optimum distribution for the company in order to minimize thetotal transportation cost by NWCR.

3	Obtain initial solution in the following transportation problem by using VAM and LCM.	Applying

Source	D1	D2	D3	D4	D5	Availability
S1	5	3	8	6	6	1100
S2	4	5	7	6	7	900
S3	8	4	4	6	6	700
Requirement	800	400	500	400	600	

1	Explain the terminology of sequencing techniques in operations research?	Analysing	1,5
2	A book binder has one printing press, one binding machine and manuscripts of 7 different books. The time required for performing printing and binding operations for different books are shownbelow.	Applying	1,5

Book	1	2	3	4
Printingtime (hr)	20	90	80	20
Bindingtime(hrs)	25	60	75	30

Decide the optimum sequence of processing of books in order to minimize the total time required to bring out all thebooks.

1	(a)Explain two person zero sum game and npersongame? (b)Explain pay of matrix and types of strategy in game theory?	Understanding	1,2
2	Solve the following game B A: 5, 20, -10 / 10, 6, 2 / 20, 15, 18	Applying	1,5

Long Answer Type questions:

Unit –I

S. No.	Question	Blooms Taxonomy Level	Course Outcomes
	UNIT-I		
1	Let us consider a company making single product. The estimated demand for the product for the next four months are 1000,800,1200,900 respectively. The company has a regular time capacityof 800 per month and an overtime capacity of 200 per month. The cost of regular time production is Rs.20 per unit and the cost of overtime production is Rs.25 per unit. The company can carry inventory to the next month and the holding cost is Rs.3/unit/month the demand has to be met every month. Formulate a linear programming problem for the above situation.	Applying	1,5
2	Solve the following LP problem using simplex method. Maximize $6x_1 + 8x_2$ S.T $x_1 + x_2 \le 10, 2x_1 + 3x_2 \le 25, x_1 + 5x_2 \le 35$ $x_1, x_2 \ge 0$	Applying	1,5
3	Solve the following LPP by Big-M penalty method Minimize $z = 5x_1 + 3x_2$ S.T $2x_1 + 4x_2 \ge 12, 2x_1 + 2x_2 \ge 10, 5x_1 + 2x_2 \ge 10$ and $x_1, x_2 \ge 0$	Applying	1,5
4	Solve the following LPP by two phase method Minimize $z = 3x_1 + 4x_2$ S.T $2x_1 + 3x_2 \le 8, 5x_1 + 2x_2 \ge 12, x_1, x_2 \ge 0$	Applying	1,5
5	a. Explain what is meant by degeneracy in LPP? How can this besolved? b. Solve the following LP problem by two phasemethod. Maximize $z = 5x_1 + 8x_2$ S.T $3x_1 + 2x_2 = 3$ $x_1 + 4x_2 \le 4$ $x_1 + x_2 \ge 5$ $x_1 + x_2 \ge 0$	Applying	1,5

6	A firm produces three types of biscuits A,B,C it packs them in arrestments of two sizes 1 and 11. The size 1 contains 20 biscuits of type A, 50 of type B and 10 of type C. the size 11 contains 10 biscuits of the A, 80 of type B and 60 of type C. A buyer intends to buy at least 120 biscuits of type A, 740 of type B and 240 of type C. Determine the least number of packets he should buy. Write the dual LP problem and interrupt your answer.	Applying	1,5
	UNIT-II		
1	A company has factories at F_1, F_2 and F_3 that supply products to ware houses at W_1, W_2 and W_3 .The weekly capacities of the factories are 200,160 and 90 units. The weekly warehouse requirements are 180,120 and 150/units respectively. The unit shipping costs in rupees are as follows. Find the optimal solution	Applying	1, 5

	W1	W_2	W_3	Supply
F1	16	20	12	200
F2	14	8	18	160
F3	26	24	16	90
Demand	180	120	150	450

2	a. Write the Mathematical representation of an assignmentmodel? b. Briefly explain about the assignment problems in OR and applications of assignment in OR?	Analysing	1, 5
3	Different machines can do any of the five required jobs, with different profits resulting from each assignments shown in the adjusting table. Find out maximum profit possible through optimal assignment.	Applying	1,2

Jobs	**Machines**				
	A	B	C	D	E
1	30	37	40	28	40
2	40	24	27	21	36
3	40	32	33	30	35
4	25	38	40	36	36
5	29	62	41	34	39

4	A typical assignment problem, presented in the classic manner. Here there are five machines to be assigned to five jobs. The numbers in the matrix indicate the cost of doing each job with each machine. Jobs with costs of M arediallowed assignments. The problem is to find the minimum cost matchingofmachines to jobs.	Applying	1, 5

	J1	J2	J3	J4	J5
M1	M	8	6	12	1
M2	15	1	7	M	1

			2			0		
	M3	10	M	5	14	M		
	M4	12	M	12	16	15		
	M5	18	17	14	M	13		
5	A salesman has to visit five cities A,B,C,D,E. The intercity distances are tabulated below.						Applying	1, 5
		A	B	C	D	E		
	A	-	12	24	25	15		
	B	6	-	16	18	7		
	C	10	11	-	18	12		
	D	14	17	22	-	16		
	E	12	13	23	25	-		
	Find the shortest route covering all the cities.							
	UNIT-III							
1	Six jobs go first on machine A, then on machine B and last on machine C. The order of completion of jobs has no significance. The following table gives machine time for the six jobs and the three machines. Find the sequence of jobs that minimizes elapsed time to complete the jobs.						Applying	1, 5
	Jobs	Processing Time						
		Machine A	Machine B	Machine C				
	1	8	3	8				
	2	3	4	7				
	3	7	5	6				
	4	2	2	9				
	5	5	1	10				
	6	1	6	9				
2	Solve the following sequence problem, given an optimal solution when passing is not allowed.						Applying	1, 5
	Machines	Jobs						
		A	B	C	D	E		
	M1	11	13	9	16	17		
	M2	4	3	5	2	6		
	M3	6	7	5	8	4		
	M4	15	8	13	9	11		
3	A firm is considering the replacement of a machine, whose cost price is Rs.12,200 and its shop value is Rs.200. From experience the running (maintenance and operating) costs are found to be as follows. Year 1 2 3 4 5 6 7 Runningcost 200 500 800 1200 1800 2500 3200 40 When should the machine be replaced?						Applying	1, 2

<table>
<tr><td>4</td><td>The management of a large hotel is considering the periodic replacement of light bulbs fitted in it's room .There are 500 rooms in the hotel and each room has 6 bulbs. The management is now following the policy of replacing the bulbs as they fail at the total cost of Rs:3 per bulb .The management feels that this cost can be reduced to Rs:1 by adopting the group replacement method. On the basis of the information given below, evaluate The alternative and make a recommendation to the management
<table>
<tr><td>Month of use</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Percent of bulbs failing by that month</td><td>10</td><td>25</td><td>50</td><td>80</td><td>100</td></tr>
</table></td><td>Applying</td><td>1, 5</td></tr>
<tr><td>5</td><td>The data collected in running a Machine the cost of which is Rs:60,000 are given below
<table>
<tr><td>Resale value</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Resale value (Rs)</td><td>42,000</td><td>30,000</td><td>20,400</td><td>14,400</td><td>9,65</td></tr>
<tr><td>Cost of Spares (Rs)</td><td>4,000</td><td>4,270</td><td>4,880</td><td>5,700</td><td>6,80</td></tr>
<tr><td>Cost of Labour</td><td>14,000</td><td>16,000</td><td>18,000</td><td>21,000</td><td>25,0</td></tr>
</table>
Find the time when the machine should be replaced?</td><td>Applying</td><td>1,2</td></tr>
<tr><td>6</td><td>Machine A costs Rs:45,000 and it's operating costs are estimated to be Rs:1,000 for the first year increasing by Rs:10,000 per year in the second year and subsequent years .Machine B costs Rs:50,000 and operating cost are Rs:2,000 for the first year and increasing by Rs:4,000 in the second and subsequent years. If at present we have a machine of type A, should we replace it with B? If so when? Assume both machines have no resale value and this future cost are not discounted?</td><td>Applying</td><td>1,5</td></tr>
<tr><td>7</td><td>Machine A costs of Rs:80,000. Annually operating cost are Rs:2,000 for the first years and they increase by Rs:15,000 every years (for example in the fourth year the operating cost are Rs:47,000).Determine the least age at which to replace the machine. If the optional replacement policy is followed. (a)What will be the average yearly cost of operating and owing the machine (Assume that the reset value of the machine is zero when replaced, and that future costs are not discounted.Another machine B cost Rs:1,00,000.Annual operating cost for the first year is Rs:4,000 and they increase by Rs:7,000 every year .The following firm has a machine of type A which is one year old. Should the firm replace it with B and if so when?
Suppose the firm is just ready to replace the M/c A with another M/c of the same type, just the the firm gets an information that the M/c B will become available in a year .What should firmdo?</td><td>Applying</td><td>1,5</td></tr>
</table>

UNIT-IV

1	Solve the following game Y1 Y2 Y3 X1 4 20 6 X2 18 12 10	Applying	1,5
2	Using the dominance property obtain the optimal strategy for both the players and determine the value of game. The payoff matrix for player A is given PLAYER -B I II III IV V PLAYER A I 2 4 3 8 4 II 5 6 8 7 8 III 6 7 9 8 7 IV 4 2 8 4 3	Applying	1,2
3	Find the range of value of P and Q that will render the entry (2,2) a saddle point for the followinggame PLAYER-B B1 B2 B3 PLAYER-A A1 2 4 5 A2 10 7 9 A3 4 P 6	Applying	1,2
4	A company is currently involved in negotiation with it's union on the upcoming wage contract positive signs in the table represent wage increase while negative sign represents wage reduction what are the optimal strategies for the company as well as the union ?what is the gamevalue? UnionStrategy C1 0.25 0.27 0.35 -0.02 C2 0.20 0.16 0.08 0.08 C3 0.14 0.12 0.15 0.03 C4 0.30 0.14 0.19 0.00	Applying	1,5
5	Two breakfast food manufacturers ABC and XYZ are competing for an increased market share. The pay off matrix, shown in the following table describes the increase in market share for ABC and decrease in market share Of XYZ. ABC | Give Coupons | Dec Price | Maintain Present Strategy | Increase Advertis Give Coupons | 2 | -2 | 4 | 1	Applying	1,5

	Decrease Price	6	1	12	3			
	Maintain Present Strategy	-3	2	0	6			
	Increase advertising	2	-3	7	1			

6	Use the graphical method for solving the following game and find the value of the game **Player B**						Applying	1, 5
	Player A		B1	B2	B3	B4	Probability	
		A1	2	2	3	-2	P1	
		A2	4	3	2	6	P2	
7	What are inventory models? Enumerate various types of inventory models and describe them briefly						Understanding	1,5
8	The production department of a company required 3,600kg of raw material for manufacturing a particular item per year. It has been estimated that the cost of placing an order is Rs.36 and the cost of carrying inventory is 25% of the investment in the inventories, the price is Rs.10/kg. help the purchase manager to determine and ordering policy for raw material, determine optimal lot size						Applying	1, 5
9	Purchase manager places order each time for a lot of 500 no of particular item from the available data the following results are obtained, inventory carrying 40%, ordering cost order Rs.600, cost per unit Rs.50 annual demand 1000,find out the loser to the organization due to his policy.						Applying	1,5
10	A dealer supplies you the following information with regards to an product that he deals in annual demand =10,000 units, ordering cost Rs.10/order, Price Rs.20/unit. Inventory carrying cost is 20% of the value of inventory per year. The dealer is considering the possibility of allowing some back orders to occurs. He has estimated that the annual cost of back ordering will be 25% of the value of inventory. a. What should be the optimum no of units he should buy in 1lot? b. What qty of the product should be allowed to be backordered c. What would be the max qty of inventory at any time ofyear Would you recommend to allow backordering? If so what would be the annual cost saving by adopting the policy of backordering.						Applying	1, 5
11	The annual demand of a product is 10,000 units. Each unit costs Rs.100 if the orders are placed in quantities below 200 units. for orders above 200 or above, however the price is Rs.95. The annual inventory holding costs is 10% of the value of the item and the ordering costs is Rs.5/order. Find economic lot size?						Applying	1,5

	UNIT V		
1	Explain the terms Balking, Reneging, Jockeying.	Understanding	1, 5
2	Explain the terms single server and multiple server que length and finite and Infinite que length.	Understanding	1, 5
3	Customers arrive at box office windows being manned by a single individual, according to a poisson input process with a mean rate of 20/hr. the time required to seme a customer has an exponential distribution with a mean of 90 sec. Find the avg waiting time of customers. Also determine the avg number of customers in the system and avg queue length.	Applying	1, 2
4	A road transport company has one reservation clerk on duty at a time. He handles information of bus schedules and makes reservations customers arrive at a rate of 8 per hour and the clerk can, on an average, service 12 customers per hour. After starting your assumptions determine. a. What is the avg number of customer waiting for the service of the clerk b. What is the avg time a customer has to wait before beingused?	Applying	1, 5
5	Consider a single semen queuing system with poissions input and exponential service times. Suppose that mean arrival rate is 3 calling units per hour, the expected service time is 0.25 hours and the maximum permissible calling units is the system is two. Derive the steady state probability distribution of the number of calling units in the system. And then calculate the expected number in the system.	Applying	1, 5
6	At a railway station only one train is handled at a time. The railway track is sufficient only for two trains to wait while others are given signal to leave the station. Trains arrive at the station at an average rate of 6 per/hours and the railway station can handle them on an average of 12 per/hours. Assuming posission arrivals and exponential service distribution find the steady state probability of the various numbers of trains in the system. also find the average number of trains in the system.	Applying	1, 5
7	Explain the application of Queuing systems?	Understanding	1, 5
8	In a departmental store one cashier is there to serve the customers. And the customers pick up their needs by themselves the arrival rate is 9 customers for every 5 minutes and the cashier can serve 10 customers in 5 minutes. Assuming poisions arrival rate and exponential distribution for service rate.Find a. Average number of customers in the system b. Average number of customers in the queue of average queue length? c. Average time a customer spends in the systems Average time a customer waits before being served.	Applying	1, 5

9	A bank has two tellers working on the savings accounts. The first teller only handles withdrawals. The second teller only handles deposits. It has been found that the service time distributions for the deposits and withdrawals both are exponential with mean service time 3 min per customer. Deposition are found to arrive in a poisons fashion throughout the day with a mean arrival rate of 16/hr withdrawals also arrive in a poisons fashion with a mean arrival rate of 14/hr. what would be the effect on the average waiting time for depositors and withdrawals if each teller could handle both the withdrawals and deposits what would be the effect if this could only be accomplished by increasing the service time to 3.5 minutes?	Applying	1, 2
10	A television repairman finds that the time spent on his jobs has an exponential distribution with a mean of 30 minutes. If he repairs the sets in the order in which they came in, and if the arrival of sets follows a poission distribution with an approximate average rate of 10 per 8 hour day, what is the repairman's expected idle time each day? How many jobs are ahead of the average, set just brought in?	Applying	1, 5
11	Use dynamic programming to solve the following problem Maximize $z = x_1^2 + 2x_2^2 + 4x_3$ S.T $x_1 + 2x_2 + x_3 = 8$ and $x_1, x_2, x_3 \geq 0$	Applying	1, 2
12	Use dynamic programming to solve the following problem Maximize $z = x_1^2 + 2x_2^2 + 3x_3^2$ S.T $x_1 + 2x_2 + x_3 = 8$	Applying	1, 2
13	Use Bell man's principle of optimality to find the optimum solution to the following problem. Minimize $z = y_1^2 + y_2^2 + y_3^2$ S.T $y_1 + y_2 + y_3 = 15$, $y_1, y_2, y_3 \geq 0$	Applying	1, 5
14	Discuss dynamic programming with suitable examples?	Understanding	1, 5
15	Solve the following LP problem by dynamic programming approach. Maximize $z = 8x_1 + 7x_2$ S.T $2x_1 + x_2 \leq 8, 5x_2 \leq 2x_2 \leq 15, x_1, x_2 \geq 0$	Applying	1, 5
16	Use dynamic programming to solve the following LPP Maximize $z = 3x_1 + 5x_2$ S.T $x_1 \leq 4, x_2 \leq 6, 3x_1 + 2x_2 \leq 18, x_1, x_2 \geq 0$	Applying	1, 5
17	Max $z = 3x_1 + 4x_2$ S.T $2x_1 + x_2 \leq 40, 2x_1 + 5x_2 \leq 180, x_1, x_2 \geq 0$ solve using dynamic programming.	Applying	1, 5

<table>
<tr><td>18</td><td>Solve using dynamic programming
Max $z = 50x_1 + 100x_2$
S.T $2x_1 + 3x_2 \le 48, x_1 + 3x_2 \le 42$
$x_1, x_2 \ge 21, x_1, x_2 \ge 0$</td><td>Applying</td><td>1, 5</td></tr>
<tr><td>19</td><td>Solve using dynamic programming
Max $z = 3x_1 + 5x_2$
S.T $x_1 \le 4, x_2 \le 6, 3x_1 + 2x_2 \le 18, x_1, x_2 \ge 0$</td><td>Applying</td><td>1, 5</td></tr>
<tr><td>20</td><td>What is simulation? Discuss application of simulation?</td><td>Understanding</td><td></td></tr>
<tr><td>21</td><td>Discuss the advantages and disadvantages of simulation.</td><td>Understanding</td><td>1, 5</td></tr>
<tr><td>22</td><td>Define simulation why simulation uses. Give one application area when this technique is used in practice.</td><td>Understanding</td><td>1, 5</td></tr>
<tr><td>23</td><td>Explain what factors must be considered when designing simulation experiment.</td><td>Understanding</td><td>1, 5</td></tr>
<tr><td>24</td><td>Draw a flow chart to describe the simulation of a simple system.</td><td>Understanding</td><td>1, 5</td></tr>
<tr><td>25</td><td>Discuss types of simulations?</td><td>Understanding</td><td>1, 5</td></tr>
<tr><td>26</td><td>A company manufactures around 200 mopeds. Depending upon the availability of raw materials and other conditions. The daily production has been varying from 196 mopeds to 204 mopeds. Whose probability distribution are given below:
<table>
<tr><td>Pro/day</td><td>196</td><td>197</td><td>198</td><td>199</td><td>200</td><td>201</td><td>202</td><td>20</td></tr>
<tr><td>Probability</td><td>0.05</td><td>0.09</td><td>0.12</td><td>0.14</td><td>0.20</td><td>0.15</td><td>0.11</td><td>0.0</td></tr>
</table>
Finished mopeds are transported to a lorry that can accommo 200 mopeds. Random numbers are 82,89,78,24,53,61,18,45,04,23,50,77,54 and 10. Simulate the mopeds waiting.</td><td>Applying</td><td>1,2</td></tr>
<tr><td>27</td><td>A bakery keeps stock of a popular brand of cake. Previous experience show the daily demand pattern for the item with associated probabilities as given
<table>
<tr><td>Daily Demand (Number)</td><td>0</td><td>10</td><td>20</td><td>30</td><td>40</td><td>50</td></tr>
<tr><td>Probability</td><td>0.01</td><td>0.20</td><td>0.15</td><td>0.50</td><td>0.12</td><td>0.02</td></tr>
</table>
use the following sequence of random numbers to simulate the demand for next 10 days.Random numbers: 25,39,65,76,12,05,73,89,19,49
Also estimate the daily average demand for the cakes on the basis of the simulated data</td><td>Applying</td><td>1 ,5</td></tr>
</table>

a. **Objective questions**

JNTUH

Unit-I

1) _____ as a field, primarily has a set or collection of algorithms which act as tools for problem solving in chosen application areas.
   (a) Linear Program (b) Operations Research (c) Graphical Research (d) None of these
2) The scientific method in OR study generally involves:
   (a) Judgment phase, (b) Research phase, (c) Action phase, (d) All of the above
3) Graphs are an example of _____.
   (a) Iconic model, (b) Analogue model, (c) Symbolic model, (d) None of the above
4) Characteristic of OR is _____.
   (a) Interdisciplinary, (b Wholistic, (c) Scientific and Objective, (d) All of the above
5) The _____ is an abstraction of reality.
6) The scaled version of a real object is called _____.
7) Example of a Predictive OR model is _____ models.
8) Example of a Prescriptive OR model is _____ models.
9) Example of an Analogue OR model is _____ problem.
10) The number of phases in OR are _____.
11) Monte-Carlo Method is used to solve _____ models.
12) _____ is an application of matrix algebra used to solve a broad class of problems that can be represented by a system of linear equations.
13) If the objective and constraint functions are all linear, then the problem is called as ____.
14) The _____ method is limited to LP problems involving two decision variables and a limited number of constraints due to the difficulty of graphing and evaluating more than two decision variables.
15) The _____ method is much more powerful than the graphical method and provides optimal solution to LP problems containing thousands of decision variables and constraints.
16) The _____ of handling instances with artificial variables is the commonsense approach.
17) A LPP may be defined as the problem of maximizing or minimizing a linear function subject to _____.
18) A typical mathematical program consists of a single objective function, representing either a profit to be maximized or a cost to be minimized, and a set of constraints that circumscribe the _____.
19) The number of decision variables in graphical method of optimization is _____.
20) Pivot column is associated with _____ variable in simplex method.

Unit-II

1) The transportation model deals with shipment of commodity from _____ to _____.
2) The method of penalties is also called as _____ method.
3) The column, which is introduced in the matrix to balance the rim requirements, is
4) Transportation problem where the demand or requirement is equals to the available resource is known as _____.
5) When the total allocations in transportation model of $m \times n$ size is not equals to $m + n - 1$ then the situation is known as _____.
6) VAM stands for _____.

7) Modified Distribution Method can be called as _____ method.
8) The cost of dummy cells is taken as _____ in TP.
9) A loop drawn in method of optimizing TP should consist of at least _____ corners.
10) The transportation model is treated as balanced if _____. (a) Demand = Supply (b) Demand > Supply (c) Demand < Supply (d) None
11) When the dual is feasible, we have reached the optimal solution to both primal and dual, therefore _____ method is optimal. (a) VAM (b) MODI (c) NWCM (d) Johnson
12) To convert the transportation problem into a maximization model we have to _____. (*a*) To write the inverse of the matrix (*b*) To multiply the rim requirements by –1 (*c*) To multiply the matrix by –1 (*d*) cannot convert the transportation problem in to a maximization problem, as it is basically a minimization problem.
13) The supply at three sources is 50, 40 and 60 units respectively whilst the demand at the four destinations is 20, 30, 10 and 50 units. In solving this transportation problem _____. (a) a dummy source of capacity 40 units is needed (b) a dummy destination of capacity 40 units is needed (c) no solution exists as the problem is infeasible (d) none solution exists as the problem is degenerate.
14) In Northwest corner method the allocations are made _____. (*a*) Starting from the left hand side top corner, (*b*) Starting from the right hand side top corner (*c*) Starting from the lowest cost cell (*d*) Starting from the lowest requirement and satisfying first.
15) In transportation model the optimality test can be carried out by: (a) Stepping Stone Method, (b) Modified Distribution Method, (c) both (a) & (b), (d) None

Unit-III

1) The fundamental assumption of Johnson's method of sequencing is _____.
2) If a job has zero processing time for any machine, the job must be processed _____.
3) In 2 jobs by m machine sequencing problem _____ is fixed.
4) In 2 jobs by m machine sequencing, a line at 45° represents: (*a*) Job 1 is idle, (*b*) Job 2 is idle, (*c*) Both jobs are idle, (*d*) No job is idle.
5) In sequencing, an optimal path is one that minimizes (*a*) Elapsed time, (*b*) Idle time, (*c*) Processing time, (*d*) Ready time.
6) In jobs A to D have process times as 5, 6, 8, 4 on first machine and 4, 7, 9, 10 on second machine, then the optimal sequence is: (*a*) CDAB, (*b*) ABCD, (*c*) BCDA, (*d*) DBCA.
7) The fundamental assumption for Johnson's algorithm of sequencing is _____ rule.
8) In n jobs by 2 machine sequencing problem, if two jobs J1 and J2 have equal processing times on both machines M1 and M2, then we can choose sequence _____.
9) The objective of sequencing problem is _____. (*a*) To find the order in which jobs are to be made (*b*) To find the time required for completing all the jobs on hand. (*c*) To find the sequence in which jobs on hand are to be processed to minimize the total time required for processing the jobs. (*d*) To maximize the effectiveness.
10) If there are 'n' jobs and 'm' machines, there will be _____ sequences of doing the jobs. (a) $n \times m$, (b) $(n!)m$, (c) n^m (d) $(n!)^m$
11) In general sequencing problem will be solved by using _____. (*a*) Hungarian Method. (*b*) Simplex method. (*c*) Johnson and Bellman method, (*d*) Flood's technique.
12) In solving 2 machine and '*n*' jobs, the following assumption is wrong: (*a*) No passing is allowed (*b*) Processing times are known, (*c*) Handling time is negligible, (*d*) The time of processing depends on the order of machining.
13) The following is one of the assumptions made while sequencing '*n*' jobs on 2 machines: (a) Two jobs must be loaded at a time on any machine. (b) Jobs are to be done alternatively on each machine. (c) The order of completing the jobs has high significance.

(d) Each job once started on a machine is to be performed up to completion on that machine.

14) This is not allowed in sequencing of '*n*' jobs on two machines: (*a*) Passing, (*b*) loading (*c*) Repeating the job (*d*) Once loaded on the machine it should be completed before removing from the machine.
15) At petrol Bunk, when '*n*' vehicle are waiting for service then the service rule used is _____. (*a*) LIFO (*b*) FIFO (*c*) Service in Random Order (*d*) Service by highest profit
16) In replacement analysis, the maintenance cost is a function of _____.
17) When money value changes with time @ r, then discount factor for n^{th} year = _____.
18) _____ cost refers to uniform annual equivalent loss in capital.
19) Running cost refers to uniform annual equivalent amount to be spent to _____ and _____ the equipment.
20) Replacement decision is very much common in _____ stage.

Unit-IV

1) If the value of the game is zero, then the game is known as _____.
2) When the game is played on a predetermined course of action, which does not change throughout game, then the game is said to be _____.
3) If the losses of player *A* are the gains of the player *B*, then the game is known as
4) If there are more than two persons in a game then the game is known as _____.
5) The list of courses of action with each player is called _____.
6) The corresponding strategy of each player at equilibrium point is _____ strategy.
7) If minimax value is equal to maximin value, then the game is said to have _____.
8) Ram and Shyam play a game with two types of coins 5 ps and 10 ps. Each draws one coin randomly and if the sum is even Ram wins the coins, otherwise Shyam. The value of the game is _____.
9) The game whose payoff matrix is null matrix is _____ game.
10) The games with saddle points are: (*a*) Probabilistic in nature, (*b*) Normative in nature (*c*) Stochastic in nature, (*d*) Deterministic in nature.
11) When Minimax and Maximin criteria matches, then _____. (*a*) Fair game exists. (*b*) Unfair game exists, (*c*) Mixed strategy exists (*d*) Saddle point exists.
12) Identify the wrong statement: (*a*) Game without saddle point is probabilistic (*b*) Game with saddle point will have pure strategies (*c*) Game with saddle point cannot be solved by dominance rule. (*d*) Game without saddle point uses mixed strategies.
13) In case, there is no saddle point in a game then the game is: (*a*) Deterministic game, (*b*) Fair game, (*c*) Mixed strategy game, (*d*) Multi player game.
14) In case, there is no saddle point in a game then the game is: (*a*) Deterministic game, (*b*) Fair game, (*c*) Mixed strategy game, (*d*) Multi player game.
15) When there is dominance in a game then: (*a*) Least of the row $\geq$ highest of another row (*b*) Least of the row $\leq$ highest of another row (*c*) Every element of a row $\geq$ corresponding element of another row. (*d*) Every element of the row $\leq$ corresponding element of another row.
16) When the game is not having a saddle point, then the following method cannot be used to solve the game: (*a*) Linear Programming method, (*b*) Minimax and maximin criteria (*c*) Algebraic method (*d*) Graphical method.
17) A competitive situation is known as _____. (*a*) Competition (*b*) Marketing (*c*) Game (*d*) None of the above.
18) Theory of games and economic behavior was published by _____. (*a*) John Von Neumann and Morgenstern (*b*) John Flood (*c*) Bellman and Neumann (*d*) A K Erlang

19) A necessary and sufficient condition for a saddle point to exist is the presence of a _____ element which is both a minimum of its row and a maximum of its column. (*a*) payoff (*b*) 2 x 2 matrix (*c*) n x 2 matrix (*d*) 2 x m matrix

20) Stock level at which fresh order should be placed is known as _____.

Unit-V

1) The period between two successive arrivals is called _____.
2) Service distribution represents the _____ in which the number of customers leaves the system.
3) At a gas filling station, mean arrival rate is Poisson at 3 per hr and mean filling time is distributed exponentially at 10 min. Then the expected number of units in the system is
4) The customer move from one queue will be tempted to join another queue because of its smaller size is known as _____.
5) A lottery system follows _____ queue discipline.
6) Waiting line problem arise because of _____. (a) Too much demand, (b) Too less demand, (c) both (a) & (b), (d) None
7) A queuing model is called multi-server model if the system has number of parallel channels each with server: (a) 1, (b) 0, (c) > 1, (d) None
8) If the number of arrivals during a given time period is independent of the number of arrivals that have already occurred prior to the beginning of time interval, then the new arrivals follow _____ distribution.
9) The characteristics of queue model are independent of: (a) Service pattern (b) Number of service points (c) Limit of queue, (d) Queue discipline
10) A customer leaving the queue thinking that he may not get service due to the lengthy queue is called _____. (a) Balker (b) Reneger (c) Jockeyer (d) Dissatisfied
11) As per queue discipline the following is not a negative behavior of a customer: (*a*) Balking (*b*) Reneging (*c*) Boarding (*d*) Collusion.
12) The expediting or follow up function in production control is an example of _____. (*a*) LIFO (*b*) FIFO (*c*) SIRO (*d*) Pre emptive.
13) In M/M/S: N/FIFO the following does not apply: (*a*) Poisson arrival (*b*) Limited service (*c*) Exponential service (*d*) Single server
14) The dead bodies coming to a burial ground is an example of _____. (*a*) Pure Birth Process (*b*) Pure death Process (*c*) Birth and Death Process (*d*) Constant rate of arrival
15) The system of loading and unloading of goods usually follows _____. (*a*) LIFO (*b*) FIFO (*c*) SIRO (*d*) SBP
16) A steady state exist in a queue if _____. (*a*) $\lambda > \mu$ (*b*) $\lambda < \mu$ (*c*) $\lambda \leq \mu$ (*d*) $\lambda \geq \mu$
17) Which of the following relation is not true:
(*a*) $L_s = L_q + \frac{1}{\lambda}$ (*b*) $L_s = \lambda W_s$ (*c*) $L_q = \lambda W_q$ (*d*) $W_s = W_q + \frac{1}{\mu}$

GATE

1) (a) Solution of Maximize 4x1 + 6x2 + x3, subject to 2x1 -x2 + 3x3 $\leq$ 5 ; x1, x2, x3 $\geq$ 0 is _____ (b) Adding the constraint x2 $\leq$ 2, solution becomes _____. (GATE 2000)
2) A company places orders for supply of two items A and B. The order cost for each of the items is Rs.300/order. The inventory carrying cost is 18% of the unit price per year per unit. The unit prices of the items are Rs.40 and Rs.50 respectively. The annual demands are 10,000 and 20,000 respectively. (a) EOQ for item A is _____ (b) Thee minimum total cost for both items is _____ (c) A supplier is willing to give a 1% discount on price on item A, if the order quantities for each item are 1000 units or more. Is it profitable to avail the discount ____ (Specify Yes/No)? (GATE 2000)

3) In a single server infinite population queuing model, arrivals follow a Poisson distribution with mean $\lambda = 4$ per hour. The service times are exponential with mean service time equal to 12 minutes. The expected length of the queue will be _____. (a) 4 (b) 3.2 (c) 1.25 (d) 5 (GATE 2000)
4) A company is offered the following price breaks for order quantity. If order quantity is between 0 – 100 then Price is Rs. 150 and Price is Rs. 100 for Order quantity above 100. Order cost is Rs.60 per order while the holding cost is 10% of the purchase price. If the annual requirement is 1000 units, EOQ = _____. (GATE 2001)
5) A furniture manufacturer produces chairs and tables. The wood-working department is capable of producing 200 chairs or 100 tables or any proportionate combinations of these per week. The weekly demand for chairs and tables is limited to 150 and 80 units respectively. The profit from a chair is Rs.100 and that from a table is Rs.300. (a) The optimum product mix for maximizing the profit is _____ (b) The maximum profit is _____. (c) If the profit of each table drops to Rs.200 per unit, then the profit is _____. (GATE 2002).
6) An item can be purchased for Rs.100. The ordering cost is Rs.200 and the inventory carrying cost is 10% of the item cost per annum. If the annual demand is 4000 units, the economic order quantity (in units) is: (a) 50 (b) 100 (c) 200 (d) 400 (GATE 2002).
7) A company has introduced a new product with fixed cost of Rs.200 per week and unit variable cost of Rs.7. The product is sold to a retailer with a quantity discount as per the following schedule: Quantity 0 – 99 units then Unit price Rs.10 and for quantity 100 units onwards unit price is Rs.8. The range of quantities sold for the company to earn profit is _____? (GATE 2002).
8) Arrivals at a telephone booth are considered to be Poisson, with an average time of 10 minutes between successive arrivals. The length of a phone call is distributed exponentially with mean 3 minutes. The probability that an arrival does not have to wait before service is _____. (a) 0.3 (b) 0.5 (c) 0.7 (d) 0.9 (GATE 2002).
9) A manufacturer produces two types of products, 1 and 2, at production levels of x1 and x2 respectively. The profit is given is 2x1 + 5x2.The production constraints are $x1 + 3x2 \leq 40$; $3x1 + x2 \leq 24$; $x1 + x2 \leq 10$; $x1, x2 \geq 0$. The maximum profit which can meet the constraints is (a) 29 (b) 38 (c) 44 (d) 75 (GATE 2003).
10) Market demand for springs is 8, 00,000 per annum. A company purchases these springs in lots and sells them. The cost of making a purchase order is Rs.1, 200. The cost of storage of springs is Rs.120 per stored piece per annum. The economic order quantity is _____. (a) 400 (b) 2,828 (c) 4,000 (d) 8,000 (GATE 2003).
11) A company produces two types of toys: P and Q. Production time of Q is twice that of P and the company has a maximum of 2000 time units per day. The supply of raw material is just sufficient to produce 1500 toys (of any type) per day. Toy type Q requires an electric switch which is available at 600 pieces per day only. The company makes a profit of Rs.3 and Rs.5 on type P and Q respectively. For maximization of profits, the daily production quantities of P and Q toys should respectively be: (a) 100, 500 (b) 500, 100 (c) 800, 600 (d) 1000, 1000 (GATE 2004).

IES

1) (IES 2008) Which one of the following statements is not correct? (a) A linear programming problem with 2 variables and 3 constraints can be solved by Graphical Method (b) In big-M method if the artificial variable cannot be driven out it depicts an optimal solution (c) Dual of a dual is the primal problem (d) For mixed constraints either big-M method or two phase method can be employed

2) (IES 2008) In order for a transportation matrix which has six rows and four columns not to degenerate, what is the number of occupied celled in the matrix?
(a) 6 (b) 9 (c) 15 (d) 24
3) (IES 2008) In the basic EOQ model, if demand is 60 per month, ordering cost is Rs. 12 per order, holding cost is Rs. 10 per unit per month. What is the EOQ?
(a) 12 (b) 144 (c) 24 (d) 28
4) (IES 2008) In the basic EOQ model, if lead time increases from 5 to 10 days, the EOQ will: (a) double (b) decrease by a factor of two (c) remain the same (d) The data is insufficient to find EOQ
5) (IES 2008) The inter-arrival times at a tool crib are exponential with an average time of 10 minutes and the length of the service time is assumed to be exponential with mean 6 minutes. The probability that a person arriving at the booth will have to wait is equal to:
(a) 0.15 (b) 0.40 (c) 0.42 (d) 0.69
6) (IES 2008) In a single server queuing system with arrival rate of 'λ' and mean service time of 'μ' the expected number of customers in the system is λ/(μ- λ). What is the expected waiting time per customer in the system?
(a) $\lambda^2/(\mu-\lambda)$ (b) (μ- λ) (c) 1/(μ- λ) (d) (μ- λ)/ λ
7) (IES 2009) While solving a linear simplex method, if all ratios of the right hand side to the coefficient in the key row become negative, then the problem has which of the following types of solution?
(a) An unbounded solution (b) Multiple solution (c) A unique solution (d) No solution
8) (IES 2009) In a linear programming problem, which one of the following is correct for graphical method?
(a) A point in feasible region is not a solution to the problem
(b) One of the corner points of the feasible region is not the optimum solution
(c) Any point in the positive quadrant does not satisfy the non-negativity constraint
(d) The lines corresponding to different values of objective functions are parallel.
9) (IES 2009) Which one of the following is true in case of simplex method of linear programming? (a) The constants of constraints equation may be positive or negative (b) Inequalities are not converted into equations (c) It cannot be used for two-variable problems (d) The simplex algorithm is an iterative procedure
10) (IES 2009) A linear programming problem with mixed constraints (some constraints of ≤ type and some of ≥ type) can be solved by which of the following method? (a) Big-M method (b) Hungarian method (c) Branch and bound technique (d) Least cost method

Websites Addresses:

1) www.informs.org
2) http://nptel.iitm.ac.in/video.php?subjectId=112106134
3) http://www.wikihow.com/Use-the-Hungarian-Algorithm
4) http://www.youtube.com/watch?feature=player_embedded&v=BUGIhEecipE
5) http://canmedia.mcgrawhill.ca/college/olcsupport/stevenson/om3ce/IOM_applets/hungarianMethod/Hungarian.htm
6) *www.scienceofbetter.org/*

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6) Dr Ravi Vadlamani, Institute for Development & Research in Banking Technology, Hyderabad
7) Dr V.N.Sastry, Professor, IDRBT, Hyderabad
8) Dr. N. Karmarkar, Fellow of Bell Laboratories
9) Dr. Kiran Seth, Associate Professor, IIT-Delhi
10) Dr. G. Srinivasan, Professor, IIT-Chennai

Journals(National&International):

1) Annals of Operations research
2) Computers and Industrial engineering
3) Computers and operations research
4) Decision sciences
5) Engineering Management
6) European Journal of Industrial Engineering
7) European Journal of Operational research
8) IIE transactions
9) INFOR
10) Informs

1) Introduction to Operation Research
2) Linear Programming Problem – Formulation & Graphical solution
3) Linear Programming Problem – Simplex method & Artificial variables techniques
4) Transportation Problem– Basic Feasible Solution methods & MODI method
5) Assignment Problem– Hungarian Algorithm & Traveling Salesman Problem
6) Flow Shop & Job Shop Sequencing
7) Replacement of items that deteriorate with time
8) Group Replacement
9) Theory of Games– Minimax (maximin) Criterion and Dominance Principle
10) Theory of Games– Graphical method

Case Studies / Small Projects:

1) Transportation Problem
2) Assignment Problem
3) Quadratic assignment problem
4) Traveling Salesman Problem
5) Travelling salesman problem with multiple objective
6) Vehicle Routing Problem
7) Replacement of Items that deteriorate with time
8) Replacement of Items that fail completely
9) Shortest Path Problem
10) Capital Budgeting Problem
11) Facility Location Problem
12) Forecasting
13) Inventory Management
14) Multi-echelon inventory system
15) Flow Shop Sequencing
16) Job Shop Sequencing
17) Planning & Scheduling Applications
18) Assembly Line Balancing
19) Three-dimensional cutting/packing of boxes on shelves
20) Three-dimensional cutting/packing of container loading
21) Three-dimensional cutting/packing of container loading with weight restrictions
22) Production Planning